

REMARKS

Claims 13-33 are pending in this application. By this Amendment, claims 15 and 16 are amended. Support for the amendments to claims 15 and 16 can be found in the specification as originally filed, for example, at page 20, lines 10-13, page 21, line 26 - page 22, line 12, and in Example 1, page 31, line 21 - page 33, line 27, and in claims 15 and 16 as originally filed.

The courtesies extended to Applicants' representative by Examiner Kunemund at the interviews held November 12, 2003 and June 18, 2004, are appreciated. The reasons presented at the June 18, 2004 interview as warranting favorable action are incorporated into the remarks below and constitute Applicants' record of the interview.

I. Pending Claims 13-33 Define Patentable Subject Matter

The Office Action rejects claims 13-33 under 35 U.S.C. §103(a) over U.S. Patent No. 6,162,708 to Tamatsuka in view of Iida et al. (ELECTROCHEMICAL SOC'Y PROC., Vol. 99-1, pp. 499-510). Applicants respectfully traverse this rejection.

Claims 13, 14, 25 and their dependent claims

Independent claim 13 sets forth a "silicon single crystal wafer grown by the Czochralski method, which is doped with nitrogen, and has an N-region for the entire plane and an interstitial oxygen concentration of 5-8 ppma." Claims 17, 19, 21 and 23 depend from claim 13. Independent claim 14 sets forth a "silicon single crystal wafer grown by the Czochralski method, which is doped with nitrogen, and has an interstitial oxygen concentration of 5-8 ppma, and in which at least void type defects and dislocation clusters are eliminated from the entire plane." Claims 18, 20, 22 and 24 depend from claim 14. Independent claim 25 sets forth a "method for producing a silicon single crystal wafer, wherein the wafer is produced from a single crystal pulled under such conditions that the crystal should have an N-region for the entire plane and interstitial oxygen concentration

should become 5-8 ppma when the crystal is grown by the Czochralski method with nitrogen doping." Claims 26-33 depend, directly or indirectly, from claim 25.

For at least the reasons set forth below, Applicants respectfully submit that claims 13, 14 and 25, and their respective dependent claims, would not have been obvious over the cited references.

Tamatsuka describes a silicon single crystal wafer doped with nitrogen and having an epitaxial layer formed on the surface layer portion of the silicon single crystal wafer. See Tamatsuka, claim 1. Epitaxial wafers, such as that disclosed by Tamatsuka, are formed by forming an epitaxial layer on a silicon wafer. In these cases, the crystal quality of the epitaxial layer is very important, but the crystal quality and defect distribution of the supporting wafer is not. Silicon wafers used as support substrates for epitaxial wafers are generally produced from low cost crystals which are grown as quickly as possible.

Tamatsuka relates to a silicon single crystal wafer having an epitaxial layer. Tamatsuka does not teach or suggest a silicon single crystal wafer having an N-region for the entire plane, as set forth in claims 13 and 25. In addition, Tamatsuka neither discloses nor suggests the oxygen concentration range of claims 13, 14 and 25. Since Tamatsuka does not define the oxygen concentration as specifically being 8 ppma or less, an OSF ring generated by nitrogen doping can not be inactivated. See Specification, page 19, lines 19-26.

The Office Action asserts that the nitrogen doping in Tamatsuka would inherently produce an N-region across the entire wafer as claimed. Contrary to this unsupported assertion, a silicon single crystal doped with nitrogen will not automatically produce a crystal having an N-region for the entire plane. Doping with nitrogen will enlarge the N-region of a crystal, but will not necessarily produce an N-region across the entire plane. See Specification, page 6, lines 14-19; page 10, line 27 to page 11, line 10. A crystal having an N-region for the entire plane will not be obtained unless the crystal is pulled under a

condition such that the entire plane will become an N-region, even if the crystal is doped with nitrogen. That is, a crystal having an N-region for the entire plane will be obtained only if the crystal is pulled, doped with nitrogen, and an F/G value is controlled at a predetermined value. Mere doping of a crystal with nitrogen will not inherently, in all instances, result in an N-region over the entire plane, as claimed.

The Office Action asserts that the sole difference between Tamatsuka and independent claims 13, 14 and 25 is the F/G value. Applicants disagree with this characterization. Applicants respectfully submit that the asserted F/G value referenced by the Office Action is not included in any of the pending independent claims. Rather, the F/G value appears only in dependent claims 26 and 27. The Office Action thus fails to allege how the claimed invention of at least the independent claims would have been obvious over the cited references. In addition, in silicon crystal growth, the F/G value is not necessarily controlled to the same value in different techniques, even when the F/G value is controlled, because different defect distributions are desired, depending on the technique employed.

Further, although Tamatsuka discloses nitrogen doping, controlling an F/G value is not disclosed or suggested in the reference. Tamatsuka does not disclose, teach or suggest pulling a crystal under conditions suitable for producing an N-region across the entire plane.

The example of Tamatsuka makes clear that Tamatsuka discloses a crystal pulled at a pulling rate of 1.0 millimeters per minute or 1.8 millimeters per minute. An F/G value, a ratio of the pulling rate F and the temperature gradient G, is not disclosed or controlled. Nor does Tamatsuka teach or suggest any reason for controlling the F/G value, or that different results could or would be obtained. In addition, the pulling rate disclosed in Tamatsuka is much faster than the exemplary pulling rates disclosed in the examples of this application, which fall in the range of 0.49 through 0.77 millimeters per minute. The higher speed of

Tamatsuka results in the lack of formation of an N-region, rather than formation of an N-region over the entire plane, as recited in claims 13, 14 and 25.

Furthermore, the oxygen concentration disclosed in Tamatsuka is 18 ppma or less. This oxygen concentration range is very broad, and is not defined as the specific, extremely low oxygen concentration of 5-8 ppma, as set forth in claims 13, 14 and 25. In particular, the Examples of Tamatsuka describe oxygen concentrations of 16 ppma (Example 1), 10.5-17.5 ppma (Example 2), 10-18 ppma (Example 3), and 16 ppma (Example 4), all well above the range claimed in claims 13, 14 and 25. Nowhere does Tamatsuka disclose, teach or suggest having the oxygen concentration in the specific, narrow range of claims 13, 14 and 25.

The criticality of the specific range of oxygen concentration set forth in claims 13, 14 and 25 is explained in detail in the specification. In particular, the specification discloses that OSFs and dislocation loops are generated in the silicon crystal when the oxygen concentration is higher than 8 ppma. See Specification, page 19, lines 8-26. The specification also discloses that, when the oxygen concentration is below 5 ppma, the silicon crystal is completely defect free, with neither grown-in defects or OSFs and dislocation loops. See Specification, page 13, line 16 - page 14, line 1; page 22, lines 3 - 12; Example 1, page 31, line 21 - page 33, line 27. Thus, when the oxygen concentration is in the range of 5-8 ppma, as set forth in claims 13, 14 and 25, a silicon wafer, with IG gettering ability and having bulk defects due to oxygen precipitation, but without OSFs or dislocation loops, can be prepared. See Specification, Example 2, page 34, line 18 - page 35, line 14.

Thus, the fact that Tamatsuka practically discloses only oxygen concentrations between 10 and 18 ppma is important because Applicants discovered that OSFs and dislocation loops are not generated in an oxygen concentration of 8 ppma or less, but are produced in oxygen concentrations of 10 ppma or more. See Specification, page 8, lines 3-10; page 19, lines 9-21. Tamatsuka does not disclose, teach or suggest that any

benefits could be obtained by lowering the oxygen concentration to within the range of 5-8 ppma, as set forth in claims 13, 14 and 25, rather than using an oxygen concentration of 10-18 ppma as disclosed by the Examples of Tamatsuka.

In the silicon wafers of claims 13, 14 and 25, which have an oxygen concentration range of 5-8 ppma, OSF rings generated by nitrogen doping can be inactivated. In contrast, Tamatsuka teaches, practically, an oxygen concentration of 10-18 ppma, OSF rings, generated by nitrogen doping in the silicon wafers, cannot be inactivated. Tamatsuka does not teach or suggest that different results could or would be obtained if the oxygen concentration is lowered, or that such different results would still be suitable for Tamatsuka's purposes.

By utilizing an OSF region expanded by nitrogen doping while the oxygen concentration is 5-8 ppma, OSFs are not generated, and a defect-free wafer can be obtained from a crystal containing no dislocation loops originating from OSF nuclei. See Specification, page 19, lines 9-21. In contrast to the assertion of the Office Action, Tamatsuka does not teach or suggest that OSFs can be prevented in the grown silicon crystal. At column 3, lines 10-25, Tamatsuka explains that by subjecting the wafer to the heat treatment, nitrogen or oxygen in the surface layer of the wafer can be out-diffused, and the crystal defects can be decreased. That is, Tamatsuka discloses the formation of a denuded zone, not the existence or absence of OSFs. Further, the next paragraph of Tamatsuka and column 8, lines 50-61 of Tamatsuka disclose that when a heat treatment is performed in an atmosphere of hydrogen gas and inert gas, OSFs are not generated because OSFs are an oxidation induced stacking fault; however, when a heat treatment is performed in an oxygen atmosphere, OSFs may be generated. In contrast, the instant application discloses prevention of OSF generation by controlling the oxygen concentration to be 8 ppma or less, which is never described in Tamatsuka.

Further, since fine oxide precipitates exist in the silicon wafers of claims 13, 14 and 25, the wafers have gettering ability (IG ability). See Specification, page 20, lines 14-20. That is, since a silicon single crystal wafer that is doped with nitrogen, has an N-region for the entire plane and an interstitial oxygen concentration of 5-8 ppma is used, a silicon single crystal wafer that is defect-free and has appropriate gettering ability (i.e., a defect-free wafer with IG ability) can be provided. This is affirmed and demonstrated in the examples in the present application. In Example 2, a crystal was pulled under an oxygen concentration of 7 ppma and an N-region was obtained, such that micro defects originating from oxygen precipitation were observed and the wafer had high gettering ability. See Specification, page 34, line 18 - page 35, line 14.

Claims 13, 14 and 25 set forth a specific, narrower range of oxygen concentration, a range not taught or suggested by the cited references. Claims 13, 14 and 25 illustrate the recognition that OSFs are not generated by utilizing an OSF region expanded by nitrogen doping while the oxygen concentration is 5-8 ppma, and that a defect-free wafer can be made from a silicon single crystal that contains no dislocation loops originating from OSF nuclei. See Specification, page 8, lines 3-10; page 19, lines 9-21. Since fine oxide precipitates exist in the silicon wafer, the wafer has IG ability. As a result, the silicon single crystal wafer, doped with nitrogen, has an N-region for the entire plane and an interstitial oxygen concentration of 5-8 ppma. Thus, a silicon single crystal wafer that is defect-free and has appropriate gettering ability (IG ability) can be obtained.

Tamatsuka, therefore, does not teach or suggest the subject matter set forth in claims 13, 14 and 25 or their dependent claims. Combining Tamatsuka with Iida does not cure the defects of Tamatsuka.

Iida discloses a silicon wafer that is doped with nitrogen and has an N-region for the entire plane. However, the silicon wafer disclosed in Iida does not have an interstitial oxygen

concentration of 5-8 ppma. Unlike claims 13, 14 and 25, Iida can not obtain a defect-free wafer with gettering ability (IG ability).

In particular, Iida discloses a silicon wafer that is doped with nitrogen, has an N-region for the entire plane and an interstitial oxygen concentration of 6.4-4.8 ppma. However the oxygen concentration of Iida is represented by ASTM '79 as described on page 500 of Iida. The oxygen concentration defined in the claimed invention is represented by JEIDA as described at, for example, page 19, lines 9-11. The relation between JEIDA and ASTM is $JEIDA \times 1.6 \approx ASTM$ '79. See Shimura, Semiconductor Silicon Crystal Technology, p. 233 (attached). Therefore, the oxygen concentration of 6.4-4.8 ppma (ASTM '79) described in Iida is 4.0~3.0 ppma by JEIDA, which is below the concentration range specified in claims 13, 14 and 25. Thus, Iida does not disclose a wafer having the oxygen concentration of 5-8 ppma (JEIDA) as in claims 13, 14 and 25, and does not teach or suggest increasing the oxygen concentration to be in the range of 5-8 ppma, as claimed.

Even if Tamatsuka is combined with Iida, the combination does not teach or suggest that a silicon wafer that is doped with nitrogen, has an N-region for the entire plane and the interstitial oxygen concentration of 5-8 ppma will provide a wafer that is defect-free and has gettering ability (IG ability). The cited references do not describe the oxygen concentration of 5-8 ppma. In fact, any combination of the references would provide a wafer having an oxygen concentration either well above the claimed range, consistent with the examples of Tamatsuka, or well below the claimed range, consistent with the requirements of Iida. Moreover, neither cited reference teaches or suggests attempting to obtain a defect-free wafer that has gettering ability (IG ability).

Accordingly, one of ordinary skill in the art would not have derived the subject matter of independent claims 13, 14 and 25, or likewise their dependent claims, from the combination of the cited references.

Claims 15 and 16

Independent claim 15 sets forth a "silicon single crystal wafer, which is doped with nitrogen, has an N-region for the entire plane, and has an interstitial oxygen concentration of less than 5 ppma, and one main surface of the silicon single crystal wafer is subjected to an EG treatment." Independent claim 16 sets forth a "silicon single crystal wafer, which is doped with nitrogen, has an interstitial oxygen concentration of less than 5 ppma, in which at least void type defects and dislocation clusters are eliminated from the entire plane, and the main surface of the silicon single crystal wafer is subjected to an EG treatment."

For at least the reasons set forth below, claims 15 and 16 would not have been obvious over the cited references.

Tamatsuka describes the silicon single crystal wafer as doped with nitrogen and having an epitaxial layer formed in the surface layer portion of the silicon single crystal wafer. See Tamatsuka, claim 1. Tamatsuka does not relate to, and does not teach or suggest, a wafer having an N-region for the entire plane, as set forth in claims 15 and 16. In addition, Tamatsuka neither discloses nor suggests the oxygen concentration range of claims 15 and 16.

The Office Action asserts that the nitrogen doping in Tamatsuka would inherently produce an N-region across the entire wafer as claimed. As discussed above, doping with nitrogen will enlarge the N-region of a crystal, but will not necessarily produce an N-region across the entire plane. See Specification, page 6, lines 14-19; page 10, line 27 to page 11, line 10. A crystal having an N-region for the entire plane will be obtained only if the crystal is pulled, doped with nitrogen, controlling an F/G value to a predetermined value. Mere doping of a crystal with nitrogen will not inherently, in all instances, result in an N-region over the entire plane, as claimed.

The Office Action asserts that the sole difference between Tamatsuka and claims 15 and 16 is the F/G value. Applicants disagree with this characterization. As described above,

Applicants respectfully point out that the asserted F/G value referenced by the Office Action is not included in any of the pending independent claims, including independent claims 15 and 16. Rather, the F/G value appears only in dependent claims 26 and 27, which ultimately depend from independent claim 25. The Office Action thus fails to allege how the claimed invention of at least independent claims 15 and 16 would have been obvious over the cited references.

Although Tamatsuka discloses nitrogen doping, controlling an F/G value is not disclosed or suggested in the reference. Tamatsuka does not disclose, teach or suggest pulling a crystal under the conditions to produce an N-region across the entire plane.

As discussed above with respect to claims 13, 14 and 25, Tamatsuka does not disclose or suggest any particular F/G value. Nor does Tamatsuka disclose or suggest any reason for controlling the F/G value, or that different results could or would be obtained. In addition, for at least the reasons discussed above, the higher speed of the pulling rates disclosed in Tamatsuka in fact results in the lack of formation of an N-region, rather than an N-region over the entire plane as required in the claimed invention.

Further, Tamatsuka discloses a very broad oxygen concentration of 18 ppma or less. In contrast, claims 15 and 16 set forth a specific, extremely low oxygen concentration of less than 5 ppma. Nowhere does Tamatsuka disclose, teach or suggest having the oxygen concentration in the specific, narrower range of claims 15 and 16.

Tamatsuka discloses only oxygen concentrations between 10 and 18 ppma. In addition to the benefits discussed above with respect to oxygen concentrations of 5-8 ppma, Applicants discovered that if the oxygen concentration is less than 5 ppma, the crystal is completely free from not only OSFs and dislocation loops, but also from various other defects. See Specification, page 8, line 2 - page 9, line 4; page 22, lines 3-7. When an oxygen concentration of less than 5 ppma is used, as required by claims 15 and 16, the wafer

shows extremely good defect and electric characteristics. See Specification, page 8, line 24 - page 9, line 4; page 22, lines 3-7. But because such a wafer does not contain bulk defects, it lacks gettering ability. See Specification, page 22, lines 7-8. Therefore, an EG treatment may be performed to impart gettering ability. See Specification, page 22, lines 9-12.

Claims 15 and 16 set forth a specific, narrower range of oxygen concentration, a range not taught or suggested by the cited references. Claims 15 and 16 illustrate the recognition that a silicon single crystal wafer that simultaneously is defect-free and possesses gettering ability (EG ability) can be obtained by the silicon single crystal wafer that is doped with nitrogen, has an N-region for the entire plane and an interstitial oxygen concentration of less than 5 ppma, and is subjected to an EG treatment. Such a wafer is disclosed for the first time in this application and is not disclosed, taught or suggested by Tamatsuka.

For at least these reasons, Tamatsuka does not teach or suggest the subject matter of independent claims 15 and 16. Tamatsuka does not teach or suggest limiting the oxygen concentration to less than 5 ppma, as recited in claims 15 and 16. Nor does Tamatsuka teach or suggest that the N-region should be for the entire plane, as claimed. Combining Tamatsuka with Iida does not cure the defects of Tamatsuka.

Iida discloses a silicon wafer that is doped with nitrogen and has an N-region for the entire plane. But unlike claims 15 and 16, Iida can not obtain a defect-free wafer with either IG or EG gettering ability.

As discussed above, Iida discloses a silicon wafer which is doped with nitrogen, has an N-region for the entire plane and an interstitial oxygen concentration of 6.4-4.8 ppma by ASTM '79 (but 4.0~3.0 ppma by JEIDA). Thus, the Iida wafer has an oxygen concentration of less than 5 ppma but is not subjected to an EG treatment. Accordingly, the Iida wafer does not have the gettering ability (EG ability) of claims 15 and 16. Iida neither describes nor suggests a defect-free wafer with gettering ability. Contrary to the assertion in the Office

Action, Iida does not disclose, teach or suggest any "after treatment" to produce EG gettering ability.

Even if Tamatsuka is combined with Iida, the combination does not teach or suggest that a silicon wafer that is doped with nitrogen, has an N-region for the entire plane and the interstitial oxygen concentration of less than 5 ppma and is subjected to an EG treatment will provide a wafer that is defect-free and has EG gettering ability. Although Iida describes an oxygen concentration of 5 ppma or less, Iida does not combine this oxygen concentration with an EG treatment and, contrary to the Office Action's assertion, no "after treatment" is disclosed. Moreover, neither cited reference teaches or suggests attempting to obtain a defect-free wafer that has EG ability. Accordingly, one of ordinary skill in the art would not have derived the subject matter of claims 15 and 16 from the combination of the cited references.

For at least these reasons, claims 15 and 16, and by the same reasoning their dependent claims, would not have been obvious over Tamatsuka in view of Iida.

Accordingly, Applicants respectfully request reconsideration and withdrawal of the rejections under 35 U.S.C. §103(a).

II. Conclusion

In view of the foregoing, it is respectfully submitted that this application is in condition for allowance. Favorable reconsideration and prompt allowance of claims 13-33 are earnestly solicited.

Should the Examiner believe that anything further would be desirable in order to place this application in even better condition for allowance, the Examiner is invited to contact the undersigned at the telephone number set forth below.

Respectfully submitted,



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